Comparative Analysis of Welded Joint Mechanical Properties by utilizing Gas and Arc Welding Methods With 7018 and 6013 Electrodes

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Abstract: This paper explores the mechanical properties of weld joints, focusing on three key parameters: hardness, tensile strength, and impact strength of mild steel weld joints. The experimental investigation involves the use of gas welding and arc welding with 7018 and 6013 electrodes. The primary objective is to compare the obtained results with previous research findings. The findings reveal that gas weld joints exhibit higher tensile strength (504.33 MPa) and impact strength (56.9 J/cm^2) compared to arc welding. However, 6013 electrode arc welding demonstrates superior hardness (158.17 BHN). These outcomes provide valuable insights for industries in selecting optimal base materials for weld joints subjected to significant stress, facilitating informed decision-making in welding applications.

1. Introduction

Welding is integral to numerous industries, with various techniques offering specific advantages in terms of efficiency, precision, and material compatibility. Gas welding is known for its versatility and cost-effectiveness, while arc welding, particularly in its different forms such as

TIG and MIG, excels in precision and strength. These welding methods are critical in industries like automotive, aviation, and manufacturing, where the reliability of joints is paramount.

Dhaliwal et al. explored dissimilar metal welding between T91 (ferritic) and 304SS (austenitic) using SMAW and GTAW, showing GTAW's superiority in achieving higher impact strength, attributed to carbon diffusion and carbide formation in the heat-affected zone (HAZ)(1) . Kumar et al. found that GTAW resulted in stronger joints with fewer defects compared to GMAW when welding AISI 304 and Monel 400, demonstrating GTAW's ability to produce cleaner welds with defined grain boundaries (2). Ramji et al. also highlighted TIG's advantage in welding Aluminum 6063 alloys, achieving superior tensile strength and hardness due to finer grains formed with Al + 5% Mg filler, in contrast to the dendritic structures produced by MIG welding (3).Lala et al. investigated a hybrid MIG and SAW process on mild steel, finding that the combined process demonstrated higher weld zone hardness compared to standalone SAW, indicating the potential for improved mechanical properties in specific applications (4). Ramakrishnan et al. focused on TIG welding dissimilar stainless steels (AISI 304 and AISI 316) and found a clear relationship between increased current levels and higher tensile strength, with the specimen welded at 60 A achieving the highest tensile strength of 528.36 MPa (5). Chetan et al. and Balasubramanian et al. compared TIG and FSW on aluminum alloys and found that FSW consistently produced superior mechanical properties, including higher hardness, due to grain refinement and solid-state bonding, making it a strong alternative to traditional fusion welding methods (6).Paula Pinto et al. compared energy absorption in welds produced by RSW and MIG, with RSW showing higher energy absorption, highlighting its efficiency in certain applications where energy distribution is critical (7). Nagaraja et al. studied the effects of heat treatment on AISI 4140 steel, demonstrating that proper heat treatment significantly enhances the mechanical properties of welded joints, thus reinforcing the importance of process optimization (8) Abban et al. explored aluminum-tin alloys, finding that increased tin content reduced hardness but also increased ductility(9). Jamilu et al. investigated Duplex Stainless Steel (DSS) welded using GTAW and SMAW, showing that GTAW resulted in higher tensile strength, hardness, and impact energy, with the cooling rate playing a crucial role in achieving optimal ferrite-austenite transformation (10). TIG welding, particularly when current and gas flow are controlled, demonstrates superior performance in terms of tensile strength and microstructure refinement. However, excessive heat input can reduce its mechanical properties, emphasizing the need for precise control during the process (11). FSW, on the other hand, offers advantages in terms of solid-state bonding, low energy consumption, and higher mechanical properties, particularly in aluminum alloys .Comparative analyses between these methods show that while TIG welding excels in precision and microstructural integrity, FSW often outperforms in terms of energy efficiency and minimal defects (12). MIG welding, though cost-effective, generally results in lower mechanical properties and a wider HAZ, which limit its use in high-strength applications (13). Studies on alloy-specific welding parameters, such as those on Al-Mg alloys, have demonstrated how microalloying elements and optimized welding conditions can further enhance the performance of welded joints .(14,15)

The objective of this research is to provide a comprehensive comparative analysis of arc welding and gas welding techniques, highlighting their parameters like hardness, impact and tensile strength. By exploring the fundamental principles, working mechanisms, and key variables involved in each process, we aim to establish a foundation for understanding their strengths and limitation

2. Materials and Method

This study examines the mechanical properties of welded joints produced through gas and arc welding techniques, utilizing 7018 and 6013 electrodes. The experimental approach was structured to systematically explore the tensile strength, impact resistance, and hardness of the welded joints. Mild steel was selected as the base material, with its properties, along with those of the 7018 and 6013 electrodes, outlined in detail in the study. Mild steel bars were carefully machined into specimens conforming to standardized dimensions, ensuring the uniformity necessary for reliable testing. A total of nine specimens were fabricated, from which the three best-performing samples were selected for detailed analysis based on preliminary testing outcomes. The welding processes were conducted under controlled conditions tailored to each method. Gas welding employed an acetylene-oxygen flame generated with an independent power supply, while arc welding was performed at an input voltage of 220V and an output range of 18–45V, with a current supply of 350A. Both 7018 and 6013 electrodes were applied during the welding operations, and their impacts on weld quality were systematically documented. The welding conditions were optimized to ensure consistency across samples and to produce high-quality joints for subsequent evaluation. The mechanical and chemical properties of Mild steel and electrodes are shown in Table 01 and Table 02

Chemical Composition

Element		Carbon (C)	Manganese (Mn)	Silicon (Si)	Phosphorus (P)	Sulphur (S)	Iron (Fe)	Ni (Nickel)	Cr (Chromium)	Mo (Molybdenum)
Percentage Range	Mild Steel	0.05% - 0.25%	0.25% - 0.4%	0.15% - 0.35%	0.06% (max)	0.05% (max)	Remaining			
	7018E	0.05% max	1.0 - 1.6%	0.30 - 0.65%	0.03% max	0.03% max		0.30% max	0.20% max	0.30% max
	6013E	0.08 - 0.12	0.30 - 0.60	0.20 - 0.50	0.040 (max)	0.035 (max)				

Table 1: Chemical Composition

Mechanical Properties

Property		Density	Young's Modulus (E)	Tensile Strength	Compressive Strength	Shear Strength	Poisson's Ratio	Hardness (Brinell)	Elongation at Break	Thermal Conductivity	Melting Point
Value	Mild Steel	7.85 g/cm³	200 GPa	400 - 550 MPa	400 - 600 MPa	250 MPa	0.29	120 - 250 HB	20% - 25%	50 - 60 W/(m·K)	1,370 - 1,480°C (2,500 - 2,700°F)
	7018		58,000 psi (400 MPa)	70,000 - 78,000 psi (480 - 535 MPa)				27 - 32 HRC	22%		
	6013			490 - 540				120 - 170	22 - 30		

Table 2: Mechanical Properties

To assess tensile strength, a Universal Testing Machine (UTM) was used(Figure 01). Specimens measuring 165 × 9 × 5 mm were subjected to progressively increasing loads until failure, and the force-elongation data were recorded for calculating stress and strain parameters. The Charpy impact test, conducted using a digital impact testing machine(Figure 02), evaluated the toughness of the joints. Standardized V-notch specimens were utilized, and the energy absorbed during fracture was meticulously measured to quantify impact resistance. For hardness testing, the Brinell method was employed using a UTM equipped with a carbide ball indenter(Figure 03). A preload of 12 KN was applied to the welded regions, and the resulting indentations were measured with precision instruments, enabling the computation of hardness values through the Brinell formula.

The entire workflow followed a systematic sequence. Each sample underwent testing in an environment designed to minimize external influences, ensuring that the collected data accurately. Results were analyzed to draw comparisons between the gas and arc welding methods, as well as between the two electrode types, highlighting the optimal combinations for superior joint performance.

Figure 1 Universal Testing Machine and specimen before and

Figure 2 Impact Machine and specimen after test

Figure 3 Samples after hardness test

3. Result

Stress vs strain graph is shown (Figure 6).The gas weld joint has highest stress vs strain value among these 3 samples which is 504.33 MPa and 0.026 .7018 has better stress but less strain value than 6013.

The tensile strength of Gas weld,7018 & 6013 weld joist are respectively 504.33,494.14 and 483.95 Mpa .Gas weld holds highest tensile strength(Figure 4). Absorbed energy and strength is measured in impact test. Gas weld absurd 45.5 J while 7018 and 6013 absorbed 34.4J & 31.8 J. As it absorbed more energy to break Gas weld joint ,it has highest strength 56.5 j/cm^2 among 3 samples. The other 2 samples strength are 43.1 j/cm^2 and 38.6 j/cm^2 for 7018 and 6013.(Figure 5)

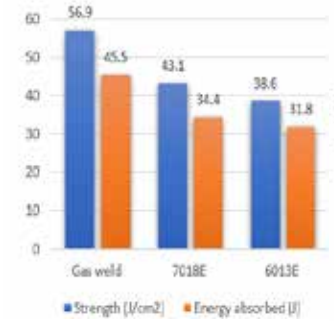

Figure 4 Strength vs Energy absorbed

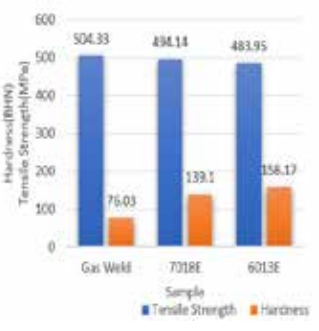

Figure 5 Tensile strength vs Hardness

Figure 6 Stress vs Strain

3.1 Comparison

Due to the absence of comprehensive comparison studies on the mechanical properties of materials concerning welding, three relevant comparative analyses have been presented to address this research gap .(Figure 07)

Figure 7 Comparison of various welding materials and methods(2,4–7,10–12,16–20)

4. Conclusion

The investigation into weld joints' mechanical properties underscores notable distinctions among gas welding, 7018 electrode arc welding, and 6013 electrode arc welding. After analyzing the results and base on the experiment the study is concluded as follows:

- Gas welding emerges as the superior choice in terms of tensile strength, surpassing 7018 and 6013 by 2.020% and 4.0410%, respectively.
- However, when considering hardness, 6013 electrode arc welding exhibits a significant advantage, boasting values 12.056% and 51.93% higher than 7018 electrode arc welding and gas welding, respectively.
- In the impact test, Gas welding demonstrates superior strength and energy absorption, outperforming 7018 electrode arc welding by 24.253% in strength and 24.395% in energy consumption.
- Similarly, compared to 6013 electrode arc welding, gas welding showcases a higher impact strength by 32.161% and greater energy absorption by 30.1098%.

5. Scope for further study

I. The optimum values of input output welding variables are not searched yet; it should be tried experimentally or by utilizing Ansys to simulate properly.

II. Microstructure analysis is yet to be done

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